

# Sneezed, stretched, and vanished: Differential brain activations of different classes of intransitive verbs

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## Abstract

This study uses fMRI to test the neural distinctions between sub-classes of intransitive verbs: unergatives, unaccusatives, and reflexives.

## 1 Introduction

According to syntactic theories, the verb assigns to its arguments thematic roles that specify the mode of their participation in the event (Dowty, 1989; Gruber, 1965; Jackendoff, 1972). The *agent* role, which indicates the entity that performs the action or brings about some change, i.e., the doer or initiator, is strongly associated with the subject position, whereas the *theme* or the *patient* role, which indicates the entity that the action is performed upon, i.e., the undergoer, is strongly associated with the object position. For example, in the sentence *The girl sneezed*, *the girl* in the subject position is the *agent*. However, *the girl* in the sentence *The girl vanished* is not actively responsible for the action described by the verb, and accordingly, is assigned the *theme* role. Unaccusative verbs are assumed to be lexically derived by an operation that reduces an argument from transitive verbs (Chierchia, 1989; Reinhart & Siloni, 2005). This operation eliminates the subject of the transitive verb or, in terms of thematic roles, eliminates its *agent* (Reinhart & Siloni, 2005), leaving the direct object (or the *theme*) the sole argument. In languages such as English, the NP must move to the subject position. To create sentences of the order NP-V for sentences with unaccusative verbs, the noun moves from its original position after the verb to the subject position (Burzio, 1986; Levin & Rappaport-Hovav, 1995; Perlmutter, 1978). In Hebrew, both the order noun-verb (NP-V) and the order verb-noun (NP-V) are acceptable.

Like unaccusative verbs, reflexive verbs, which denote an action that the *agent* applies on itself (e.g., *The girl stretched*), are derived from

transitive verbs. Note that in Hebrew reflexives have a distinctive morphological structure that distinguishes them from the transitive verbs from which they were derived. Thus, although in English the verb *stretched* can be used for both transitive and reflexive instances, in Hebrew the two verbs are distinct. The way reflexive verbs are derived from transitives is still debated. Some accounts argue that this derivation includes a lexical operation similar to the one that derives unaccusative verbs from transitive verbs, and thus include movement from object to subject position (Kayne 1988; Marantz, 1984; Pesetsky 1995). Other accounts claim that the argument of reflexive verbs, like the argument of unergative verbs, originates in the subject position. According to these accounts, reflexive verbs are the output of a lexical operation of absorption or reduction, which applies to a transitive entry, targeting its internal argument and producing an intransitive verb (Chierchia, 1989; Grimshaw, 1982; Reinhart & Siloni, 2004). Therefore, these approaches differ with respect to whether or not the derivation of reflexive verbs includes syntactic movement (leading to word order change) or not.

Here, we report two fMRI experiments that examined the patterns of cortical activation associated with the comprehension of unaccusative and reflexive verbs. This study specifically aims to examine whether, as predicted by linguistic theory, the cortical representation of unaccusatives, reflexives, and unergatives differs. Additionally, we used patterns of cortical activation in an attempt to adduce evidence that may help to decide the nature of the derivation of reflexive verbs.

## 2 General Methods

The first stage of the experimental procedure included the selection of Hebrew verbs based on several distinguishing criteria including: (1) the possibility to add possessive datives, (2) the pos-

sibility to appear in V-NP order (Siloni, 2008), and (3) the possibility to occur with reflexive pronouns. In the experiments, each verb was embedded in four sentences. The sentences in each experiment were controlled for the number of phrases, phrase structure, definiteness, and duration. The verbs were controlled for verb templates and frequency. A block design paradigm was used. Each block included four sentences and each condition repeated 7 or 8 times. Eighteen (Experiment 1) or twenty-four (Experiment 2) participants were asked to listen to the sentences and to decide whether the event described in the sentence is more likely to happen at home or not (for example, for a sentence like "Dan slept in the yellow tent", participants will press a "no" button). This semantic task ensured that participants attended to the sentences and processed them fully.

### **3 Experiment 1: The distinction between unaccusative and unergative verbs**

In this experiment (Shetreet et al., 2010), we compared unaccusative verbs (in NP-V order) to unergative verbs (with one argument) and transitive verbs (with two arguments). That is, we compare verbs that undergo lexical reduction and syntactic movement to verbs that do not. Other types of syntactic movement have shown activations in the left inferior frontal gyrus (IFG) (e.g., Ben-Shachar et al., 2003, 2004; Stromswold et al., 1996). Lexical related activation was previously revealed in several brain areas including left frontal, left temporal and left inferior parietal cortices (e.g., Fiebach et al., 2002; Keller et al., 2001; Kemeny et al., 2006; Kircher et al., 2000). A direct comparison between unaccusative and unergative verbs revealed activations in the left IFG (Brodmann area (BA) 45/46/47), left superior frontal gyrus, left middle temporal gyrus (MTG; BA 21) and right cerebellum. This indicates the brain distinguishes between unaccusative and unergative verbs, even when they appear in identical sentence structures (i.e., "*The girl vanished*" vs. "*The girl sneezed*"). These results join a growing body of findings from various methodologies and populations, suggesting evidence for the neuropsychological and psycholinguistic reality of this distinction generally, and for the analysis of unaccusative verbs specifically (Friedmann, 2007; Friedmann et al., 2008). In order to identify the activations that relate to the lexical operation and the syntactic movement of unaccusatives, and distinguish them from ac-

tivations linked to a specific difference between unaccusatives and unergatives, we performed a conjunction analysis with the comparison between unaccusatives and transitive verbs. This analysis showed activations in the left IFG (BA 45/46) and the left posterior MTG. The present study cannot conclusively determine which operation is associated with each of these areas. However, previous findings regarding the functions of these areas can give us some insights for their role in the comprehension of unaccusative verbs. The left IFG has been consistently linked to syntactic processing and syntactic movement (Ben-Shachar et al., 2004; Friedmann, 2006; Grodzinsky, 2000; Shetreet et al., 2009; Stromswold et al., 1996; Zurif, 1995), and thus its activation in our experiment may be related to the movement of the object to the subject position. The left posterior temporal areas have been associated with lexical and semantic processes and with verb processing (Demonet et al., 1992; Friederici et al., 2000; Humphries et al., 2006; Palti et al., 2007; Perani et al., 1999; Price et al., 1997). An adjunct area (left fusiform), located medially to the area identified in this experiment, was also implicated in the processing of an operation that omits complements of optional complements (Shetreet et al., 2009b). This may suggest that left MTG activation with response to unaccusatives is linked to the lexical operation.

### **4 Experiment 2: The distinction between reflexive and unaccusative verbs**

This experiment was aimed to inform the linguistic controversy regarding the derivation of reflexive verbs, and to determine whether the lexical operation that derives reflexive verbs involves the reduction of the external argument of a transitive verb or a reduction of the internal argument. In an attempt to answer this question, we compared reflexive verbs and unergative verbs. Additionally, we compared reflexives with unaccusatives, which undergo lexical reduction, as well as syntactic movement. As in Experiment 1, comparing Unaccusatives and unergatives resulted in activations in the left IFG (BA 45/46/47) and in the left posterior MTG (as well as other activations). Comparing reflexives and unergative did not reveal these areas, but instead the right MTG and the right middle frontal gyrus (MFG). Both of these areas have been linked to syntactic binding (Grodzinsky & Friederici, 2006) and was found in the binding of a noun

with its reflexive pronoun (Santi & Grodzinsky, 2007a, 2007b).

To further examine the differences between the verb classes, we defined the areas identified in the unaccusative-unergative comparison, the left IFG and the left MTG, as regions of interest (ROI). For each ROI, we computed the average beta weights and compared them using ANOVA and Tukey test. In the left IFG, activation in response to unaccusative verbs was higher than for both unergatives and reflexives. By contrast, in the left MTG, unaccusative differed significantly only from unergative verbs. It seems that the activations associated with reflexive verbs are a subset of the activations associated with unaccusative verbs (NP-V order). Specifically, this subset seems to overlap with the activation attributed to the lexical operation in the derivation of unaccusative verbs. Thus, our results support the claims that the lexical operation is involved in the derivation of reflexive verbs targets the internal argument and not the external argument. This is suggested by the absence of activation in the processing of reflexives in the left IFG, which is linked to the processing of movement of the object to subject position in unaccusative verbs.

## 5 Conclusion

Our findings indicate that brain activation is sensitive to the difference between sub-classes of intransitive verbs: unaccusatives, reflexives, and unergatives, distinguishing between verbs that undergo lexical and syntactic operations and those that do not. Specifically, we found support for the involvement of lexical and syntactic operations in the processing of unaccusative verbs (in NP-V order) and for the involvement of a lexical operation in the processing of reflexive verbs. The latter result supports the linguistic analysis according to which reflexive verbs are derived from transitive verbs by reducing the *internal* argument.

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